THE BENEFITS OF USING BOTH ADULT AND LARVAL STONEFLIES (PLECOPTERA) IN ENVIRONMENTAL SURVEYS: AN EXAMPLE FROM NEW SOUTH WALES WITH A SUMMARY OF THE AUSTRALIAN STONEFLY FAUNA

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Abstract

Freshwater environmental assessment and monitoring studies rely heavily on aquatic insect larvae because larvae are seen to directly reflect the aquatic environment they inhabit. However, the species-level taxonomy of most aquatic insects is based on the diagnostic characters found in adults. The uncertainty of correlating adult-based species with aquatic larvae means that aquatic life stages are rarely identified further than generic level, especially where there are sympatric congeners. However, Plecoptera adults are poor dispersers and generally remain near their site of emergence. Therefore, stonefly adults have the potential to provide more finely resolved species-level information about their nearby aquatic larval sites. Both adult and larval Plecoptera were collected during sampling for macroinvertebrates in a monitoring project in the Snowy Mountains, New South Wales. The results show that the collection and identification of adult stoneflies has potential for finer scale delimitation of riverine ecosystems than information provided by larvae alone. Also, adult stoneflies collected can provide information in related studies of taxonomy, ecology, biogeography, biodiversity, conservation and climate change. An updated check-list and an outline of taxonomic studies of Australian stoneflies, including all primary literature, are also presented.

Introduction

There has been a long standing division in the study of aquatic insects by ecologists and taxonomists. Whereas environmental and ecological studies are based almost exclusively on larvae, partially because larvae are seen to reflect directly the aquatic environment they inhabit, species-level taxonomy of aquatic insects is based on adults, because they present diagnostic characters such as wing venation and male genitalia. Aquatic entomologists would ideally like to identify larvae collected in surveys to species-level and thereby maximize biological and environmental information. However, in reality they frequently must settle for coarse level generic identifications, especially if the aquatic site hosts a number of sympatric, congeneric species.

Of all the entirely aquatic insect orders (Ephemeroptera, Odonata, Plecoptera, Megaloptera and Trichoptera), plecopteran adults are the poorest flyers, generally staying close to the emergence/breeding habitat and sometimes even occurring in aquatic kick-net samples. Numerous stonefly species are brachypterous, some even apterous, and adults of one North American species never emerge from the water. Adult stoneflies may be collected in the morning and during dull days as they emerge onto rocks protruding from the streams, or at other times by beating foliage along the stream margin (Theischinger 1991). Also, in winged species running, not flying is

commonly used to find food and mates. Since adults are often found in association with congeneric and probably conspecific larvae, it is likely that adults collected from vegetation, rocks and logs adjacent to a stream at a particular site have emerged from that water body.

In spite of the availability of several comprehensive keys to the larvae of the Victorian and New South Wales species (Hynes 1978, Yule 1997), species level identifications of larvae are difficult because of a lack of diagnostic characters, often made more uncertain because of the involvement of different larval instars. Moreover, the larvae of many species are still unknown.

The following study was based on surveys during 2009 for the program 'Snowy Hydro Cloud Seeding Trial: Further Studies on Aquatic Macroinvertebrates', in the Snowy Mountains of New South Wales, Australia. The monitoring team (the authors of this paper) were transported to sites mainly by helicopter. A decision was made to collect stonefly adults in addition to the normal aquatic samples, and thereby test if adults could provide significant additional information for such projects in the region.

I. The Snowy Hydro Cloud Seeding Trial Monitoring Program – Results for Plecoptera

Methods

Site locations

The sites were selected in 2007 for the Snowy Hydro Cloud Seeding Trial Monitoring Program, and aquatic larvae at the sites have been sampled annually since then. All sites are located within Kosciuszko National Park and include sites of varying altitude that are within the cloud seeding areas, plus control sites to the south of the seeding areas. The location of these sites is shown in Fig. 1.

Sampling

In November 2009, kick-net samples were taken using the standard protocol AusRivas (edge/riffle) (Turak and Wadell 2001). Subsequent to this up to 10 minutes per site were spent walking in the water and sweeping emergent and trailing vegetation around the site for adult stoneflies, using an aerial insect net (diameter 18"). All the collected stonefly material was emptied into small plastic jars containing 70% ethanol, sorted in the lab and then identified using the guide of Theischinger and Cardale (1987). A list was prepared including, for each site, geographical coordinates (latitude and longitude in decimal degrees) and altitude, numbers of males and females of adults collected by adult sampling as well as adults and larvae collected by AusRivas kick-net sampling in both edge and riffle habitats. The results were compared with the 2008 sampling results obtained from identification (by consultants) of larvae only.

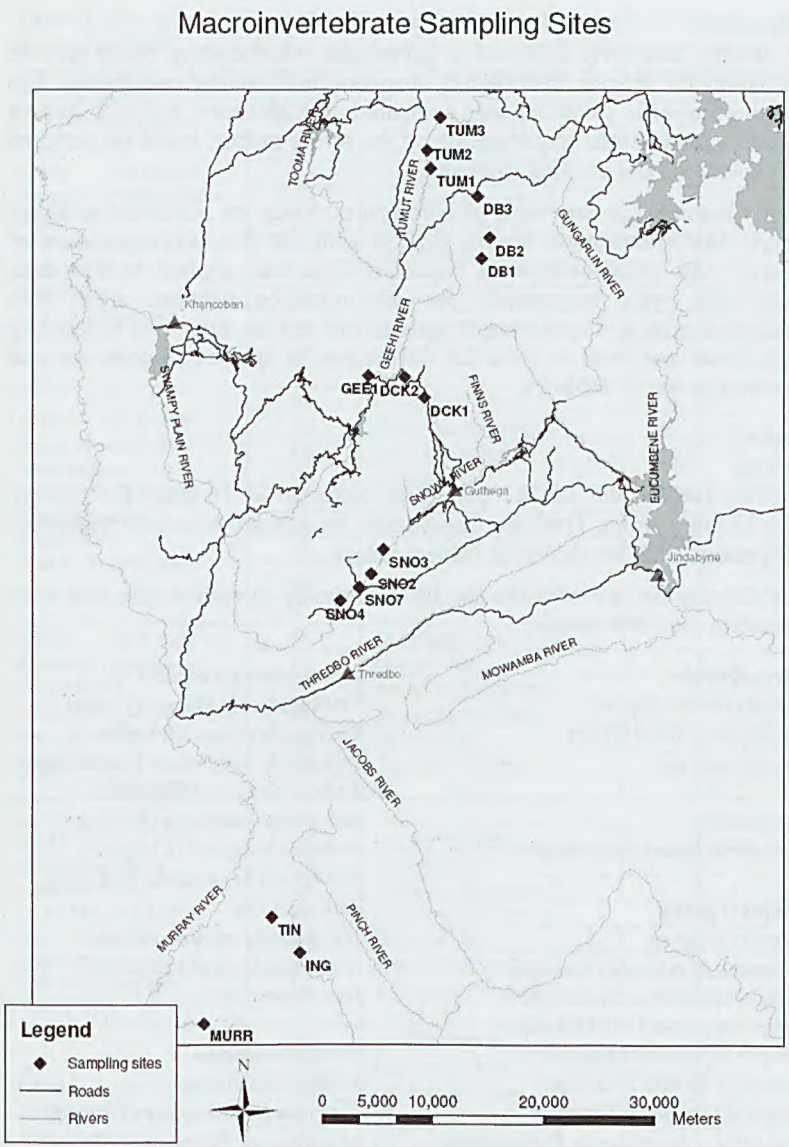

Fig.1. Location of the study sites. Source: Snowy Hydro Limited.

Analyses

The stonefly data were analysed to investigate whether they could provide information on species distribution, dispersal and habitat constraints. The location of specific stoneflies was compared with elevation and with known distribution and habitat requirements by the senior author, based on personal field experience and existing literature.

Stonefly assemblage data were also compared using the statistical software PrimerE. Multidimensional scaling (MDS) using the Bray-Curtis measure of similarity and presence/absence transformation was applied to the data. Species that were responsible for dissimilarities between sites were investigated using a simple Excel© spreadsheet and the sites were ordered by height above sea level to look for differences in species associations and elevation (shown in Table 2).

Results

Sampling

Stoneflies (adults and larvae) that were collected at 16 sites for 'Snowy Hydro Cloud Seeding Trial; Further Studies on Aquatic Macroinvertebrates' in November 2009 are shown in Table 1 below.

The following list provides the mostly confidently identified taxa that were collected in the 2009 sample:

Austroperlidae
Acruroperla atra (Samal)
Austroheptura illiesi Hynes
Austroheptura sp.

Eustheniidae
Cosmioperla kuna (Theischinger)

Gripopterygidae
Gripopterygidae sp.
Dinotoperla brevipennis Kimmins
Dinotoperla christine McLellan
Dinotoperla eucumbene McLellan
Dinotoperla fontana Kimmins
Dinotoperla hirsuta McLellan
Dinotoperla thwaitesi Kimmins
Dinotoperla subserricauda Theischinger
Dinotoperla uniformis Kimmins
Dinotoperla sp.
Illiesoperla sp.
Leptoperla sp.
Leptoperla / Riekoperla sp.
Newmanoperla thoreyi (Banks)
Riekoperla alpina McLellan
Riekoperla hynesorum Theischinger
Riekoperla karki McLellan
Riekoperla reticulata (Kimmins)
Riekoperla rugosa (Kimmins)
Riekoperla tuberculata McLellan
Riekoperla sp.
Trinotoperla montana (Riek)
Trinotoperla nivata Kimmins
Trinotoperla sp.

Notonemouridae
Notonemouridae sp.
Austrocerca tasmanica (Tillyard)
?Austrocerca ?tasmanica
Austrocercella hynesi Illies
?Austrocercella ?hynesi
Austrocercella ?tillyardi

Table 1. Plecoptera collected at sites for the Snowy Hydro Cloud Seeding Trial in November 2009. Legend: ♂ = male adults, ♀ = female adults; L = larvae; Au = Austroperlidae, Eu = Eustheniidae, Gri = Gripopterygidae, No = Notonemouridae.

Location data	Family	Species	♂	♀	L
SNO2 24/11/2009 Snowy River above Blue Lake 36.42066 S 148.33132 E Elev. 1670 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			1
	Gri	*Dinotoperla hirsuta*	1		
	Gri	*Riekoperla hynesorum*	11	12	
	Gri	*Riekoperla reticulata*	3	2	
	Gri	*Riekoperla* sp.			72
	Gri	*Trinotoperla* sp.			1
	No	*?Austrocerca ?tasmanica*		1	
	No	*Austrocercella hynesi*	2	3	
	No	sp.			6
SNO3 24/11/2009 Snowy River above Spencers Creek 36.40060 S 148.34314 E Elev. 1650 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			1
	Gri	*Riekoperla hynesorum*	16	18	
	Gri	*Riekoperla reticulata*	2	10	
	Gri	*Riekoperla* sp.			63
	Gri	*Trinotoperla* sp.			1
	No	*?Austrocercella ?hynesi*		4	
	No	*Austrocercella ?tillyardi*		2	
	No	sp.			1
SNO4 23/11/2009 Kosciusko Creek above Snowy River 36.44278 S 148.30067 E Elev. 1830 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			15
	Gri	*Leptoperla* sp.		1	
	Gri	*Riekoperla hynesorum*	7	2	
	Gri	*Riekoperla reticulata*	1	2	
	Gri	*Riekoperla* sp.		3	24
	No	*Austrocercella hynesi*	1	1	
	No	sp.			2
SNO7 23/11/2009 Snowy River above Club Lake Creek 36.43138 S 148.31946 E Elev. 1730 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			1
	Gri	*Leptoperla* sp.			1
	Gri	*Riekoperla hynesorum*	5	4	
	Gri	*Riekoperla reticulata*	3	3	
	Gri	*Riekoperla* sp.			46
	No	*Austrocercella hynesi*	1	4	
	No	*Austrocercella ?tillyardi*		1	
GEE1 24/11/2009 Geehi River above Gehi Reservoir 36.25792 S 148.32545 E Elev. 1230 m asl. Edge/Riffle Coll: G. Theischinger	Au	*Austroheptura* sp.			3
	Eu	*Cosmioperla kuna*			4
	Gri	*Dinotoperla fontana*	7	10	
	Gri	*Dinotoperla thwaitesi*	11	5	
	Gri	*Dinotoperla* sp.			8
	Gri	*Trinotoperla montana*	2		
	Gri	*Trinotoperla nivata*		1	
	Gri	*Trinotoperla* sp.			14
	Gri	*Illiesoperla* sp.			1
	No	sp.			9

Location data	Family	Species	♂	♀	L
DCK1 25/11/2009 Dicky Cooper Creek near Schlinks Hut 36.27524 S 148.38231 E Elev. 1770 m asl. Edge/Rifle Coll: G. Theischinger	Au	*Austroheptura illiesi*		1	
	Au	*Austroheptura* sp.			14
	Eu	*Cosmioperla kuna*		1	15
	Gri	*Dinotoperla hirsuta*	3	2	
	Gri	*Dinotoperla* sp.			1
	Gri	*Riekoperla hynesorum*	26	29	
	Gri	*Riekoperla karki*	3	1	
	Gri	*Riekoperla reticulata*	20	19	
	Gri	sp.			40
	No	*Austrocerca tasmanica*	1		
	No	*Austrocercella ?tillyardi*		1	
	No	sp.		1	2
DCK2 25/11/2009 Dicky Cooper Creek 36.25829 S 148.36209 E Elev. 1504 m asl. Edge/Riffle Coll: G. Theischinger	Au	*Austroheptura* sp.			4
	Eu	*Cosmioperla kuna*			4
	Gri	*Dinotoperla eucumbene*	1		
	Gri	*Dinotoperla fontana*	5	3	
	Gri	*Dinotoperla thwaitesi*	20	8	
	Gri	*Dinotoperla* sp.			4
	Gri	*Leptoperla/Riekoperla* sp.			1
	Gri	*Riekoperla alpina*	7	7	
	Gri	*Riekoperla karki*	2		
	Gri	*Riekoperla rugosa*	1	4	
	Gri	*Trinotoperla montana*	1	2	
	Gri	*Trinotoperla* sp.			13
	No	sp.			21
TUM1 23/11/2009 Tumut River above Bogong Creek 36.08654 S 148.38524 E Elev. 1400 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			8
	Gri	*Dinotoperla brevipennis*	3	8	
	Gri	*Dinotoperla fontana*	16	12	
	Gri	*Dinotoperla hirsuta*	35	32	
	Gri	*Dinotoperla thwaitesi*	9	9	
	Gri	*Dinotoperla* sp.		1	4
	Gri	*Riekoperla* sp.		1	
	Gri	*Trinotoperla nivata*		2	
	Gri	*Trinotoperla* sp.			6
	No	sp.			35
TUM2 23/11/2009 Tumut River below Bogong Creek 36.07212 S 148.38107 E Elev. 1360 m asl. Edge/Riffle Coll: G.Theischinger	Eu	*Cosmioperla kuna*			8
	Gri	*Dinotoperla brevipennis*	3	4	
	Gri	*Dinotoperla Fontana*	2	13	
	Gri	*Dinotoperla hirsute*	9	8	
	Gri	*Dinotoperla thwaitesi*	4	11	
	Gri	*Dinotoperla uniformis*	1		
	Gri	*Dinotoperla* sp.			3
	Gri	*Riekoperla tuberculata*	1		
	Gri	*Trinotoperla montana*		1	
	Gri	*Trinotoperla nivata*	3	2	
	Gri	*Trinotoperla* sp.			13
	No	sp.			4

Location data	Family	Species	♂	♀	L
TUM3 23/11/2009 Tumut River at Round Mountain 36.04476 S 148.39330 E Elev. 1310 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			8
	Gri	*Dinotoperla brevipennis*		2	
	Gri	*Dinotoperla Fontana*	9	17	
	Gri	*Dinotoperla hirsute*	4	11	
	Gri	*Dinotoperla thwaitesi*	8	8	
	Gri	*Dinotoperla* sp.			2
	Gri	*Trinotoperla montana*		3	
	Gri	*Trinotoperla nivata*	1	1	
	Gri	*Trinotoperla* sp.			5
	No	sp.			18
DB1 23/11/2009 Doubtful Creek at McCallister 36.16371 S 148.43515 E Elev. 1676 m asl. Edge/Riffle Coll: G. Theischinger	Au	*Austroheptura* sp.			2
	Eu	*Cosmioperla kuna*			10
	Gri	*Dinotoperla Fontana*		1	
	Gri	*Dinotoperla hirsute*	12	22	
	Gri	*Dinotoperla* sp.			4
	Gri	*Leptoperla* sp.		1	
	Gri	*Riekoperla hynesorum*	4	4	
	Gri	*Riekoperla karki*	2	2	
	Gri	*Riekoperla* sp.			3
	No	*Austrocerca tasmanica*	1		
	No	sp.			10
DB2 23/11/2009 Doubtful Creek at Cesjacks 36.14505 S 148.44429 Elev. 1650 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			2
	Gri	*Dinotoperla hirsuta*	4	6	
	Gri	*Dinotoperla thwaitesi*		1	
	Gri	*Dinotoperla* sp.			1
	Gri	*Riekoperla* sp.		1	1
	No	sp.			8
DB3 23/11/2009 Doubtful Creek at Grey Mares Trail 36.11081 S 148.43168 E Elev. 1540 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			2
	Gri	*Dinotoperla Fontana*		1	
	Gri	*Dinotoperla hirsute*		1	
	Gri	*Dinotoperla* sp.			1
	Gri	*Riekoperla karki*	3	1	
	Gri	*Riekoperla tuberculata*		1	
	Gri	*Riekoperla* sp.			2
	Gri	*Trinotoperla* sp.			1
	No	sp.			14
TIN 24/11/2009 Tin Mine Creek at Hut 36.70461 S 148.23559 E Elev. 1290 m asl. Edge/Riffle Coll: G. Theischinger	Au	*Acruroperla atra*		1	
	Gri	*Dinotoperla brevipennis*	1	3	
	Gri	*Dinotoperla* sp.			5
	Gri	*Riekoperla* sp.		1	
	No	sp.			4

Location data	Family	Species	♂	♀	L
MURR 24/11/2009 Upper Murray at Cowambat 36.79249 S 148.16801 E Elev. 1160 m asl. Edge/Riffle Coll: G. Theischinger	Eu	*Cosmioperla kuna*			1
	Gri	*Dinotoperla subserricauda*	1		
	Gri	*Dinotoperla thwaitesi*	3		
	Gri	*Dinotoperla* sp.			13
	Gri	*Illiesoperla* sp.			3
	Gri	*Newmanoperla thoreyi*	1		
	Gri	*Riekoperla karki*	1		
	Gri	*Riekoperla rugosa*	1	1	
ING 24/11/2009 Ingeegoodbee River above access road 36.73327 S 148.26489 E Elev. 1140 m asl. Edge/Riffle Coll: G. Theischinger	Gri	*Dinotoperla brevipennis*	3		
	Gri	*Dinotoperla christinae*			1
	Gri	*Dinotoperla fontana*		1	
	Gri	*Dinotoperla* sp.			1
	Gri	*Riekoperla rugosa*	2		
	Gri	*Riekoperla* sp.			1
	No	sp.			14

Analyses

The MDS plots of site Stonefly assemblage similarities indicated that site differences were better defined using species level adult stonefly data (shown in Fig. 3) rather than the genus/family level larval data (Fig. 2). The plot of stonefly larvae could not differentiate between sites TUM2 and TUM3, SNO2 and SNO3, and DB2, TIN and ING.

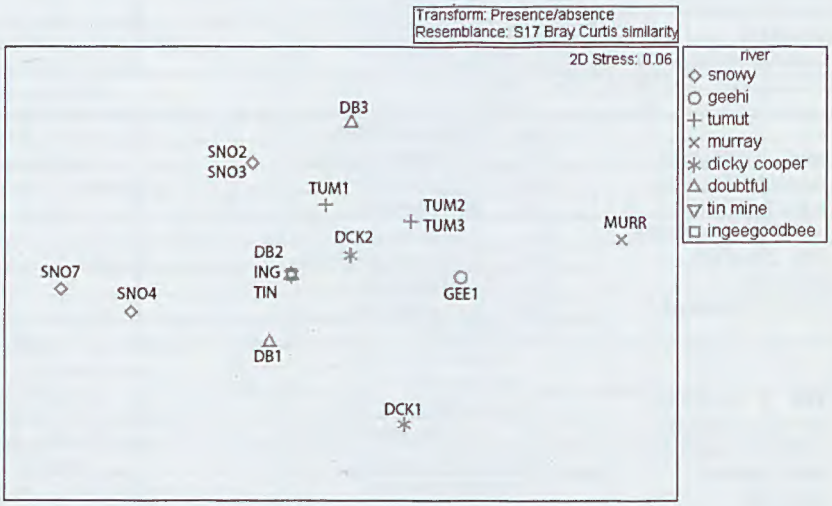

Fig. 2. MDS plot of Stonefly larvae assemblages for the study sites.

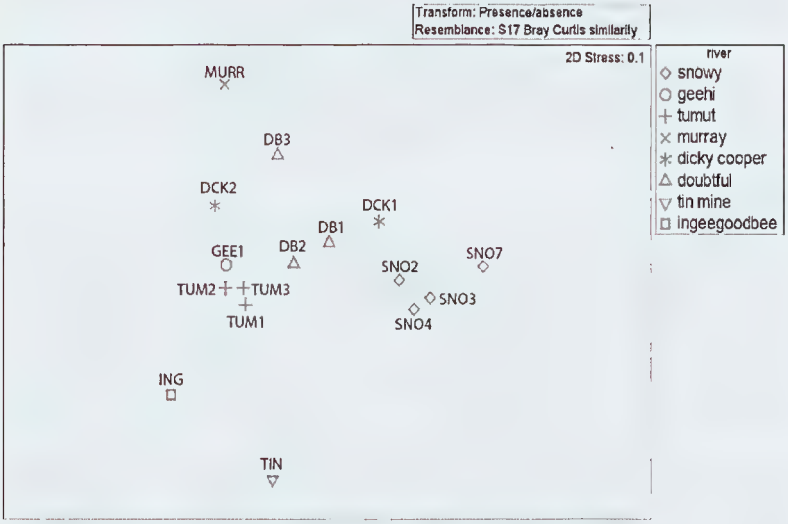

Fig. 3. MDS plot of Stonefly adult assemblages for the study sites.

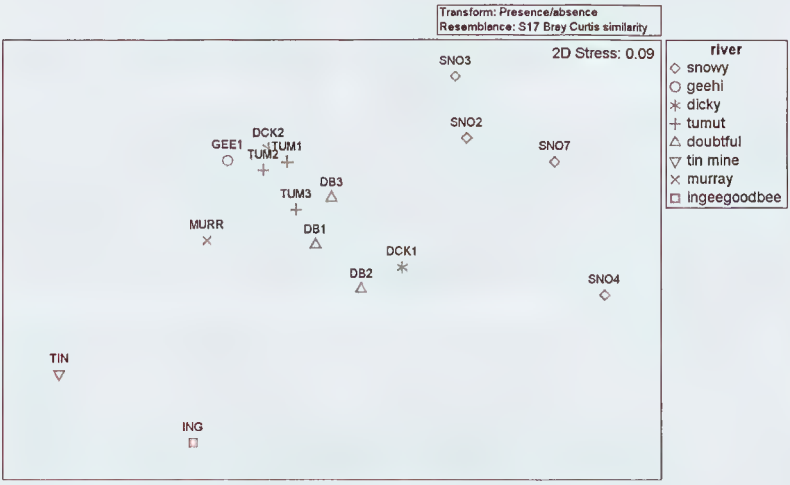

Fig. 4. MDS plot of aquatic larvae, identified to species level where possible, for the study sites riffle habitats.

The stonefly adults plot, however, identified all sites to be different and differences between rivers to be generally greater than differences between sites within each river. The exception to this was Dicky Cooper Creek, where

the two sites were dissimilar. Note that there was only one site in the Murray River, Geehi River, Ingeegoodbee River and Tin Mine Creek.

MDS plots of the aquatic larval assemblages collected from the riffle and edge habitats showed a similar general site pattern to the stonefly adult plot. The plot of the riffle larval fauna is presented in Fig. 4. The plots of the full larval assemblages were able to differentiate all sites.

Discussion

Previously, when the same Snowy Mountain sites were sampled for the monitoring program in 2008, the study only included the collection of larvae. Without adult stoneflies, only three stonefly taxa were able to be identified (by consultants) beyond family level: *Acruroperla atra*, *Cosmioperla* (? as *Sternoperla*) sp. and *Austroheptura* (? as *Tasmanoperla*) sp. By comparison, the 2009 study identified 23 different Stonefly species at the Snowy Hydro monitoring sites using adults, thus allowing analysis of differences between sites and, more importantly to the study, identification of change over time.

It appears that the geographical and habitat information from the 2009 Snowy Cloud Seeding trials, paired with confident identities for many stonefly species (see Tables 1 and 2), more than make up for the extra effort of collecting and identifying stonefly adults. The use of adult insect identifications where larvae identifications are not feasible could well prove to be an invaluable tool for the assessment of river health, biodiversity, conservation and climate change projects.

Outcomes of the study of adult stoneflies from the Snowy Hydro monitoring sites are:

Five *Dinotoperla* species were found coexisting simultaneously at the same site (TUM2) and finding diagnostic characters of these species, not only apparent in the structure of the male genitalia but also in colour and pattern of the forewings of both sexes, provides information on their ecology and may help future taxonomic and behavioural studies. Species, and particularly species assemblages, have greater indicator value for river health than family or generic-level data.

The presence in numbers of *Riekoperla alpina* in DCK2 (Dicky Cooper Creek at 1504 m), its absence in DCK1 (same creek at 1770 m) where its likely sister species *Riekoperla hynesorum* was collected in numbers, and the presence of *Riekoperla hynesorum* again in all sampled Snowy River sites (SNO2, SNO3, SNO4, SNOW07), all different in size, flow and substrate from Dicky Cooper Ck at both elevations, provides more than just very interesting ecological information. Table 2 shows clear species changes with elevation. It probably also enables taxonomists to make the first promising step to help distinguish the larvae of the *Riekoperla alpina* group morphologically without the need for expensive DNA analysis. The altitudinal detail may become significant for studies of climate change.

Table 2. Distribution of Stonefly species from the Snowy Hydro Cloud Seeding Trial. The sites are arranged with increasing elevation from left to right. The shaded boxes with crosses indicate the presence of the species at the site.

	ING	MURR	GEE1	TIN	TUM3	TUM2	TUM1	DCK2	DB3	SNO3	DB2	SNO2	DB1	SNO7	DCK1	SNO4
Stonefly adults																
Acruroperla atra				x												
Austroheptura illiesi															x	
Cosmioperla kuna															x	
Dinotoperla brevipennis	x			x	x	x	x									
Dinotoperla hirsute					x	x	x		x		x	x	x		x	
Dinotoperla eucumbene								x								
Dinotoperla christinae	x															
Dinotoperla fontana	x		x		x	x	x	x	x				x			
Dinotoperla subserricauda		x														
Dinotoperla thwaitesi		x	x		x	x	x	x			x					
Dinotoperla uniformis						x										
Riekoperla alpine								x								
Riekoperla karki		x						x	x				x		x	
Riekoperla hynesorum										x		x	x	x	x	x
Riekoperla reticulate										x		x		x	x	x
Riekoperla rugosa	x	x						x								
Riekoperla tuberculata						x			x							
Newmanoperla thoreyi		x														
Trinotoperla montana			x		x	x		x							x	
Trinotoperla nivata			x		x	x	x									
Austrocercella hynesi										x		x		x		x
Austrocercella ?tillyardi										x				x	x	
Austrocerca tasmanica												x	x		x	
Stonefly larvae																
Austroheptura sp.			x					x					x		x	
Dinotoperla sp.	x	x	x	x	x	x	x	x	x		x		x		x	
Leptoperla sp.													x	x		x
Riekoperla sp.	x			x			x	x	x	x	x	x	x	x		x
Gripopterygidae sp.															x	
Trinotoperla sp.			x		x	x	x	x	x	x		x				
Illiesoperla sp.		x	x													
Notonemouridae sp	x		x	x	x	x	x	x		x	x	x	x		x	x
Cosmioperla kuna		x	x		x	x	x	x	x	x	x	x	x	x	x	x
elevation m asl.	1140	1160	1230	1290	1310	1360	1400	1504	1540	1650	1650	1670	1676	1730	1770	1830

Changes in species assemblages and dominance situations may be indicative of any sort of pollution and may be sensitive enough to show changes relating to climatic conditions. For the family Gripopterygidae, our lists show dominance of *Riekoperla* species of the *alpina* group in high alpine sites, together with dominance of *Dinotoperla* species and the presence of some species of the *Riekoperla tuberculata* and *rugosa* groups in lower altitude sites. The existence of the *Riekoperla alpina* group in high altitude sites probably results from warm periods making available formerly glaciated areas. On the other hand, the presence of *Dinotoperla* species and species of the *Riekoperla tuberculata* and *rugosa* groups in the cooler uplands of northern New South Wales and Queensland is probably an outcome of cooler periods in the past, facilitating dispersal northward to suitable habitats. Similar cases of speciation were discussed by Peters and Theischinger (2007) for dragonflies and by Watson and Theischinger (1984) for dragonflies, stoneflies and other aquatic groups.

The fact that the appearance of adults of certain stoneflies in some regions is highly seasonal, as found in the genus *Austrocercella* in the Snowy Mountains (Theischinger 1982), is worth investigating in more detail. More than one survey a year may significantly increase the number of species per habitat (biodiversity). Changes in altitudinal and seasonal occurrence over time of these seasonal species may prove indicative for monitoring pollutants and ecological and climatic change.

The distribution of the species across the sampled sites generally supports the existing information on the poor dispersal abilities of stoneflies. The sites that have the most similar faunal assemblages are geographically close on a river continuum (*e.g.* the four Snowy River sites: Tables 1 and 2). The Geehi River site GEE1 is close to, and connected by water to, the Dicky Cooper site DCK2. The two sites on Dicky Cooper Creek, DCK1 and DCK2, are close geographically and connected by water but have dissimilar assemblages; a possible cause could be a barrier to migration created by the waterfall between the two sites. Further sampling of these sites into the future is expected to add information on stonefly dispersal in the Snowy Mountains region.

By sampling adult stoneflies at sites, a clear picture of the diversity of species at individual sites can be formed. As such, a plea is made for the inclusion of adult stonefly collecting together with standard AusRivas sampling wherever stoneflies make up a significant part of the aquatic fauna, in particular Australian alpine and montane sites.

II. Summary of the Australian Plecoptera Fauna

This could also lead to a renaissance of taxonomic and ecological stonefly studies that, after a boom in the early 1980s, have been rather stagnant for the past two decades. In order to stimulate taxonomic research, an updated check-list of the Australian Plecoptera, with state distribution data, is

presented below (Table 3). Currently, the Australian Plecoptera fauna comprises 198 valid species (and subspecies) in 26 genera and 4 families. This list is followed by an outline of taxonomic research on the group (including the primary taxonomic literature) from its beginning to the present.

Table 3. Check-list of the Australian stonefly species and their known distributions. Legend: W = Western Australia, S = South Australia, T = Tasmania, V = Victoria, N = New South Wales (including ACT), Q = Queensland.

Species	Distribution					
	W	S	T	V	N	Q
Acruroperla atra (Samal, 1921)				+	+	
Austroheptura campbelli Theischinger, 1993				+		
Austroheptura illiesi Hynes, 1974				+	+	
Austroheptura neboissi Illies, 1969				+		
Austroheptura picta (Riek, 1973)					+	+
Austropentura hynesorum Theischinger, 1988			+			
Austropentura victoria Illies, 1969				+	+	
Crypturoperla paradoxa Illies, 1969			+			
Tasmanoperla larvalis (Illies, 1969)			+			
Tasmanoperla thalia (Newman, 1839)			+			
Cosmioperla australis (Tillyard, 1921)					+	+
Cosmioperla denise (Theischinger, 1983)					+	+
Cosmioperla kuna (Theischinger, 1983)				+	+	
Cosmioperla macrops (Theischinger, 1983)						+
Cosmioperla w. wongoonoo (Theischinger, 1983)					+	+
Cosmioperla wongoonoo tropica (Theischinger, 1983)						+
Eusthenia costalis Banks, 1913			+			
Eusthenia lacustris Tillyard, 1921			+			
Eusthenia nothofagi Zwick, 1979				+		
Eusthenia reticulata (Tillyard, 1921)			+			
Eusthenia spectabilis Gray, 1832			+			
Eusthenia v. venosa (Tillyard, 1921)				+		
Eusthenia venosa brachyptera (Tillyard, 1924)					+	
Thaumatoperla alpina Burns & Neboiss, 1957			+			
Thaumatoperla flaveola Burns & Neboiss, 1957			+			
Thaumatoperla robusta Tillyard, 1921			+			
Thaumatoperla timmsi Zwick, 1979			+			
Cardioperla diversa McLellan, 1971			+			
Cardioperla edita Hynes, 1982			+			
Cardioperla falsa Hynes, 1982			+			
Cardioperla flindersi Hynes, 1982			+			
Cardioperla incerta Hynes, 1982			+			
Cardioperla lobata McLellan, 1971			+			
Cardioperla media Hynes, 1982			+			
Cardioperla nigrifrons (Kimmins, 1951)			+			
Cardioperla spinosa Hynes, 1982			+			
Dinotoperla arcuata Theischinger, 1982					+	+
Dinotoperla bassae Hynes, 1982	+		+	+	+	
Dinotoperla brevipennis Kimmins, 1951		+		+	+	
Dinotoperla bunya Theischinger, 1982						+
Dinotoperla cardaleae Theischinger, 1982						+
Dinotoperla carnarvonensis Theischinger, 1982						+
Dinotoperla carpenteri Tillyard, 1921					+	+
Dinotoperla christinae McLellan, 1971				+	+	+
Dinotoperla cobra Theischinger, 1982					+	+

Species	Distribution					
	W	S	T	V	N	Q
Dinotoperla dalrymple Theischinger, 1993						+
Dinotoperla dolichoprocta Theischinger, 1982					+	
Dinotoperla duplex Theischinger, 1982					+	+
Dinotoperla eucumbene McLellan, 1971				+	+	
Dinotoperla eungella Theischinger, 1982						+
Dinotoperla evansi Kimmins, 1951		+				
Dinotoperla fasciata Tillyard, 1921					+	+
Dinotoperla fontana Kimmins, 1951				+	+	
Dinotoperla hirsuta McLellan, 1971				+	+	
Dinotoperla hybrida Theischinger, 1984						+
Dinotoperla inermis Theischinger, 1988					+	
Dinotoperla kirrama Theischinger, 1982						+
Dinotoperla leonardi Theischinger, 1982					+	+
Dinotoperla marmorata Hynes, 1976			+			
Dinotoperla opposita (Walker, 1852)			+			
Dinotoperla parabrevipennis Theischinger, 1982					+	
Dinotoperla pseudodolichoprocta Theischinger, 1982					+	
Dinotoperla schneiderae Theischinger, 1982						+
Dinotoperla serricauda Kimmins, 1951			+	+	+	
Dinotoperla spinosa Theischinger, 1982						+
Dinotoperla subserricauda Theischinger, 1988					+	?
Dinotoperla thwaitesi Kimmins 1951				+	+	
Dinotoperla uniformis Kimmins, 1951				?	+	+
Dinotoperla vulcanica Theischinger, 1982						+
Dinotoperla walkeri Dean & St Clair, 2006				+		
Dundundra wanungra (Theischinger, 1982).						+
Eunotoperla kershawi Tillyard, 1924				+	+	
Illiesoperla australis (Tillyard, 1924)		+		+	+	
Illiesoperla austrosimplex Theischinger, 1984				+		
Illiesoperla barbara Theischinger, 1984						+
Illiesoperla brevicauda Theischinger, 1984				+	+	
Illiesoperla carnarvonensis Theischinger, 1984						+
Illiesoperla cerberus Theischinger.1984						+
Illiesoperla echidna Theischinger, 1984					+	+
Illiesoperla franzeni (Perkins, 1958)					+	+
Illiesoperla frazieri Theischinger, 1984					+	
Illiesoperla mayi (Perkins, 1958)		+	+	+	+	+
Illiesoperla tropica Theischinger, 1984						+
Kirrama abolos Theischinger, 1981						+
Kirrama naumanni Theischinger, 1993						+
Leptoperla alata Theischinger, 1984						+
Leptoperla albicincta Theischinger, 1981				+		
Leptoperla angularis Theischinger, 1981						+
Leptoperla australica (Enderlein, 1909)	+					
Leptoperla beroe Newman, 1839			+			
Leptoperla bifida Mclellan, 1971				+	+	
Leptoperla bubalus Theischinger, 1980					+	
Leptoperla cacuminis Hynes, 1974					+	
Leptoperla collessi Theischinger, 1981						+
Leptoperla commoni Theischinger, 1981						+
Leptoperla curvata Theischinger, 1980				+	+	
Leptoperla dahmsi Theischinger, 1984						+
Leptoperla kalliste Hynes, 1974				+		
Leptoperla kimminsi McLellan, 1971				+		

Species	Distribution					
	W	S	T	V	N	Q
Leptoperla longicauda Theischinger, 1988				+	+	
Leptoperla magnicauda Theischinger, 1981						+
Leptoperla membranosa Theischinger, 1988					+	
Leptoperla neboissi McLellan, 1971				+	+	
Leptoperla primitiva McLellan, 1971		+		+	+	
Leptoperla rieki Theischinger, 1981					+	
Leptoperla rotunda Theischinger, 1984						+
Leptoperla rubiconis Theischinger, 1984				+	+	
Leptoperla smithersi Theischinger, 1981					+	
Leptoperla tasmanica Kimmins, 1951		+		+	+	
Leptoperla thompsoni Theischinger, 1988						+
Leptoperla truncata Theischinger, 1980				+	+	
Leptoperla uptoni Theischinger, 1981						+
Leptoperla varia Kimmins, 1951			+			
Neboissoperla alpina McLellan, 1971				+	+	
Neboissoperla monteithi Theischinger, 1982					+	
Neboissoperla spinulata Theischinger, 2002					+	
Nescioperla curtisae Theischinger, 1982						+
Newmanoperla exigua (Kimmins, 1951)	+					
Newmanoperla hackeri McLellan, 1971				+	+	
Newmanoperla prona Hynes, 1982			+			
Newmanoperla thoreyi (Banks, 1920)		+		+	+	+
Riekoperla alpina McLellan, 1971				+	+	
Riekoperla angusta Theischinger, 1985				+	+	
Riekoperla barringtonensis Theischinger, 1985					+	
Riekoperla citrea Theischinger, 1985						+
Riekoperla compressa Theischinger, 1985				+	+	
Riekoperla cornuta Theischinger, 1985				+		
Riekoperla darlingtoni (Illies, 1968)				+		
Riekoperla elongata Theischinger, 1985					+	+
Riekoperla hynesorum Theischinger, 1985					+	
Riekoperla intermedia Theischinger, 1985				+		
Riekoperla isosceles Theischinger, 1985				+		
Riekoperla karki McLellan, 1971				+	+	
Riekoperla montana Theischinger, 1985				+	+	
Riekoperla naso Theischinger, 1981		+		+		
Riekoperla occidentalis Hynes & Bunn, 1984	+					
Riekoperla perkinsi Theischinger, 1985					+	+
Riekoperla pulchra Hynes, 1982			+			
Riekoperla reticulata (Kimmins, 1951)				+	+	
Riekoperla rugosa (Kimmins, 1951)				+	+	
Riekoperla serrata Theischinger, 1985				+		
Riekoperla tillyardi McLellan, 1971				+		
Riekoperla trapeza Theischinger, 1985				+	+	
Riekoperla t. triloba McLellan, 1971			+	+	+	
Riekoperla triloba regalis Hynes, 1982			+			
Riekoperla tuberculata McLellan, 1985				+	+	
Riekoperla williamsi McLellan, 1971				+	+	
Riekoperla zwicki Theischinger, 1985				+		
Trinotoperla comprimata Hynes, 1982			+			
Trinotoperla groomi Perkins, 1958						+
Trinotoperla hardyi Perkins, 1958			+			
Trinotoperla inopinata Hynes, 1982			+			
Trinotoperla irrorata Tillyard, 1924				+	+	
Trinotoperla maior Theischinger, 1982					+	?

Species	Distribution					
	W	S	T	V	N	Q
Trinotoperla minima Theischinger, 1982						+
Trinotoperla minor Kimmins, 1951				+	+	+
Trinotoperla montana (Riek, 1962)				+	+	
Trinotoperla mouldsi Theischinger, 1982						+
Trinotoperla nivata Kimmins, 1951				+	+	
Trinotoperla sinuosa Theischinger, 1982				+		
Trinotoperla tasmanica (McLellan, 1971)			+			
Trinotoperla woodwardi Perkins, 1958						+
Trinotoperla yeoi Perkins, 1958					+	+
Trinotoperla zwicki McLellan, 1971			+			
Austrocerca rieki Illies, 1975			+			
Austrocerca tasmanica (Tillyard, 1924)		+	+	+	+	
Austrocercella alpina Theischinger, 1984				+	+	
Austrocercella autumnalis Theischinger, 1984				+	+	
Austrocercella christinae Illies, 1975			+			
Austrocercella columbae Hynes, 1981			+			
Austrocercella c. communis Theischinger, 1984					+	+
Austrocercella communis obtusa Theischinger, 1984				+		
Austrocercella distans Theischinger, 1984				+		
Austrocercella elevata Theischinger, 1984				+		
Austrocercella forcipula Theischinger, 1984				+		
Austrocercella hynesi Illies, 1975					+	
Austrocercella i. illiesi Theischinger, 1984				+	+	
Austrocercella illiesi tarraensis Theischinger, 1984				+		
Austrocercella mariannae Illies, 1975				+	+	
Austrocercella nivalis Theischinger, 1984				+	+	
Austrocercella tillyardi (Kimmins, 1951)				+	+	
Austrocercella verna Theischinger, 1984					+	
Austrocercella weiri Theischinger, 1984					+	
Austrocercoides bullata (Kimmins, 1951)			+			
Austrocercoides kondu Theischinger, 1993			+			
Austrocercoides neboissi Illies, 1975				+	+	
Austrocercoides tunta Theischinger, 1993			+			
Austrocercoides zwicki Illies, 1975			+			
Kimminsoperla albomacula (Kimmins, 1951)			+			
Kimminsoperla biloba Illies, 1975			+			
Kimminsoperla hystrix Illies, 1975					+	+
Kimminsoperla kaputaris Theischinger. 1980					+	
Kimminsoperla mcalpinei Theischinger, 1981					+	
Kimminsiperla neboissi Theischinger, 1988			+			
Kimminsoperla williamsi Illies, 1975			+			
Notonemoura lynchi Illies, 1975			+	+		
Notonemoura maculata (Weir, 1967)				+	+	+
Tasmanocerca bifasciata (Kimmins, 1951)			+			
Total number of species group taxa = 198	**4**	**9**	**51**	**75**	**91**	**57**

Historical perspectives

The taxonomic history of Australian Plecoptera started with the description of *Eusthenia spectabilis* from Tasmania (Gray 1832). Additions of new species mostly came from contributions of one or two species each by Newman (1839), Walker (1852), Enderlein (1909), Banks (1913, 1920), Samal (1921), Burns and Neboiss (1957), Riek (1962, 1973), Weir (1967)

and Hynes and Bunn (1984). Early family/genus revisions allowed Tillyard 1921, 1924) to add twelve, Perkins (1957) to add six and Kimmins (1951) to establish 18 more species. Revisions of all families, undertaken by eminent overseas plecopterists between 1968 and 1982, provided 15 additional species described by Illies (1968, 1969, 1975), 19 by McLellan (1971), two by Zwick (1979) and 17 by Hynes (1974-1982). Theischinger (1980-2002) added a further 94 species, mainly in generic revisions based on personal collecting in the field (mainly New South Wales and Queensland) and from museum holdings. The concluding 198th Australian species (*Dinotoperla walkeri*) resulted from river health studies and was added by Dean and St Clair (2006), suggesting a closer synergy between taxonomy and environmental studies might be established. As recently as 1996, McLellan established the genus *Cosmioperla* for the Australian species previously included in *Stenoperla* McLachlan.

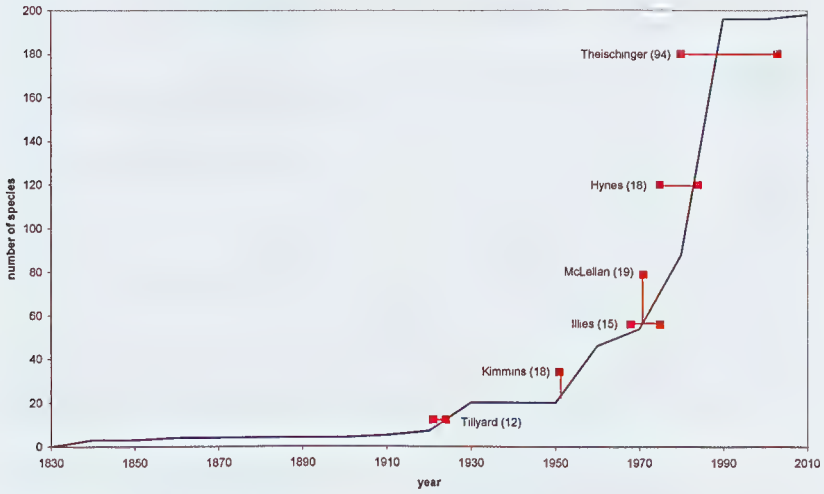

Fig. 5. Historical record of establishment of species-group taxa in Australian Plecoptera. In the above historical outline, taxa regarded as synonyms are not included. Vertical lines mark the year of single publications, horizontal lines indicate the time span between first and last publications of the author and numbers in brackets indicate the number of new species added to the fauna.

Larval taxonomy was seldom extensively covered in revisions or descriptive papers. There are, however, two comprehensive treatments by Hynes (1978) and Yule (1997) of the larvae from Victoria, and New South Wales and northern Victoria, respectively, and a more specialised publication (Tsyrlin 2001) which included only a key to the Australian stonefly genera and to the species of *Leptoperla* from Victoria. An 'Illustrated Guide to the Adults of the Australian Stoneflies (Plecoptera)', including brief descriptions and

illustrations of the adults of all Australian species, was presented by Theischinger and Cardale (1987). Based largely on this publication, the then known Australian stonefly fauna was catalogued by Michaelis and Yule (1988).

Acknowledgements

Access to the remote sites was made possible by Snowy Hydro. Specifically, John Denholm arranged for helicopter access to sites and accomodation for the field team. The helicopter pilot, Colin De Pagter, assisted with sampling at the sites. Theresa Dye of Cardno Pty Ltd provided information on site locations and previous samplings. Klaus Koop of DECCW facilitated the sampling program. The manuscript benefited greatly from critical comments from Dr D.J. Bickel (Sydney), Dr R. Marchant (Melbourne), Dr A.L. Sheldon (Crawfordville, Florida, USA) and last but not least from the editorial input of Dr A.G. Orr. The contributions of these people are gratefully acknowledged.

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